Zeitschrift: IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen

Band: 23 (1975)

Artikel: Discussion on the 2nd working session

Autor: Galambos, T.V.

DOI: https://doi.org/10.5169/seals-19833

DISCUSSION ON THE 2nd WORKING SESSION

Chairman : Prof. T. V. GALAMBOS

T. V. GALAMBOS :

We are coming to Dr. Witteveen's paper. Any questions or comments ?

G. C. LEE :

Mr. Chairman, I wonder if I can request the author to extend briefly his presentation of this very interesting research so that he may cover the following two questions

1. *The bending case : I wonder whether there are substantial differences in creep characteristics between tension and compression and if so how that is taken care of.*

2. *The second question has to do with one of his conclusions regarding the speed of heating :*

In the uniformally heated case I can understand using a small scale experimental scheme where the effect is negligibly small. However if we want to go to a larger section and particularly the non-uniform heating cases, the specific question is how to scale the heat equation so that a small model test can be interpreted in the actual case. I am interested in the case where non-uniformity may exist in the cross section particularly for heavy shapes as well as the case when non-uniformity exists longitudinaly along the column. It seems to me that the convection term in the heat equation, non-conservative in nature, is difficult to handle in the scaling.

J. WITTEVEEN :

I am very glad for these comments because this gives me the opportunity to tell a little bit more than is possible in only ten minutes.

Your first question was whether there is any significant difference in creep properties in bending and compression. First I must say that we did not investigate the creep phenomenon itself. We just investigated the influence of the heating rate of steelmembers on its critical temperatures. Because at temperatures of more than about 300°C steel appears to creep, the heating rate possibly may be of importance. So, instead of determining the creep properties itselves, we chose a more pragmatic approach. This is done by investigation of the influence of different heating rates on the critical temperature of steelmembers. As far as bending is concerned we performed small scale tests on beams.

These beams were heated with different heating rates in the range of 5°C/min till 50°C/min. Also the load-level was varied, while the midspan deflection was measured during each test.

The critical temperature was defined as the temperature at which a maximum deflection of 1/40 th of the span was reached. We did not find for those beams any significant influence of the rate of heating on the critical temperature. The same appeared to hold true for other deflection criteria. For columns, as I told you just before, we did not find any significant influence of the heating rate as well. So, as far as we are interested in the effect of the difference of creep properties on the critical temperature of steelmembers under the different applied heat conditions, the same conclusions can be given for bending as for compression.

Concerning the second question, dealing with scale-problems at non-uniform heating I should like to say the following :

Generally spoken, in steel structures under real fire conditions the heat distribution in the cross-section as well as in longitudinal direction will be non-uniform. This will obviously result in varying mechanical properties and thermal elongations and/or stresses. It must be expected that the mechanical response of a steelmember will be influenced by these effects. Indicating scale laws to simulate these effects are thought to be extremely difficult and not practical.

To solve problems like this, in our opinion first the basis problem (i.e. data, the column with uniform temperature distribution) has to be solved. With the experimental theoretical solutions can be checked. Knowing the theoretical solution for this case, it will be possible to give theoretical solution in case of non-uniform temperature distributions.

Of course such calculations are deterministic. To get a more detailed insight in non-uniform heating of structures use can be made of more sophisticated calculations on a basis of probability concepts.

<u>B.G. JOHNSTON</u> :

Dr. Beedle has asked me to extend further my suggestion to differentiate between the traditional tangent modulus theory and the extension to steel columns with residual stress. In the traditional tangent modulus theory (as originally enunciated by Engesser) one can go directly from a non-linear stress-strain curve of a material in compression to the column strength curve. The relationship is independent of cross section. Shanley showed that the tangent modulus load represents a true bifurcation of equilibrium, and he pointed the way to the later computer evaluation of maximum column strength slightly greater than the tangent modulus load. Shanley made possible the extension of tangent modulus theory to the analogous critical load theory of a steel column with a bi-linear stress-strain curve and a bi-symmetric pattern of residual stress. But the fact remains that there is no direct relationship between the stress-strain curve of structural steel and the column strength curve in the traditional pre-Shanley or Engesser tangent modulus theory because the shape of cross-section is also involved.

Now while I am on that topic I would like to put down for the record the fact that the original concept of the residual stress effect in steel columns was developed intuitively at Lehigh University in the mid 1940's as an outgrowth of tests on box girders by I. Madsen which had demonstrated the fact that residual stress does indeed lower the buckling strength of both columns and plates.

Lehigh University proposed that this effect be researched under the direction of a committee of Column Research Council on materials which was then under the chairmanship of Dr. William Osgood. After accepting this assignment Dr. Osgood became personally quite interested in this topic and he prepared independantly and off the record (without submitting his findings back to the committee) his theoretical paper on the topic. He assumes incidentally a parabolic distribution of residual stress as I remember it.

T. BARTA :

I would like to add some comments to the problem which you have raised now. I think the most precise answer to this question is due to Euler. Euler has basically two definitions of his critical load : the one which is usually referred to as the Euler load, and another one, which he gave in an earlier paper where he used what he called the "moment of stiffness". Now this concept contains special cases -all the definitions of tangent moduli and so on- and is basically more general because it refers to the proper stiffness of a member and Euler is even precise in stating how to get this moment because he proposes, and apparently never did it, to do some flexural tests on specimens and to find from them what this moment is. Now this is probably a more realistic approach to the problem. Later on the concept of stress was invented, which is absolutely purely a mathematical concept. Nobody could ever measure a stress, but we can measure our strains, and strains contain a lot in a point and these are also mathematical abstractions. We are using complicated procedures of integrating over the cross section and so on but the probably best definition still is the stiffness of member tested for bending and then an approximation to it would be the various definition given here for the tangent and other moduli.

L.S. BEEDLE :

First a comment on your historical review there Bruce, I can't let such a discussion go by without us recognizing the work of Dr. Ch. Yang. He was the one who carried out the first theoretical explanations of the buckling strength of centrally loaded columns with residual stresses. This was at the same time that Dr. Osgood was carrying out his work. It was Dr. Yang who recognized that the buckling strength of a member with residual stress could be represented by the tangent modulus concepts taking into account that portion of the cross section that remains elastic.

Back to the point of "definitions". There is not time to discuss it now, but it is something that I really think we should think about. You spoke, Bruce of three definitions : the "critical load", "buckling" and "tangent modulus" load. Is not it the latter that you were speaking of in terms of a tangent modulus load that would include a homogeneous characteristic of the stress-strain reliationship ? just wonder if that is not turning too far back into history. The aluminium industry, as I understand it, and in explaining the light gauge thin walled welded and cold-formed members those two industries in the U.S. are very much based on the shall we call it post-1947 tangent modulus statement. This is something I think we should consider.

J. STRATING :

I just want to make a historical remark also because I want to give credit to those who deserve it. I want to point out that it was a Dutchman who already before Euler proposed that the buckling load of the column was a function of a constant over L^2. He determined this relation apparently from actual tests on masonry structures. These tests showed that a constant was involved and that L^2 was in it too. He also concluded that the dimensions of the column play a role in this constant. This Dutchman was Van Musschenbroek ; he did this in

Leiden, a well known and famous University, in 1729.

B. G. JOHNSTON :

With reference to Dr. Beedle's comment, the aluminium industry does use the tangent modulus load as a basis for column strength but in this application there is no need to differentiate between the pre-Shanley and post-Shanley concepts. In a general way the concepts are essentially the same for steel and aluminium. But in structural steel we cannot go directly from a small compressive test specimen to the column strength curve as in the case of aluminium or stainless steel.

T.V. GALAMBOS :

I think the historical section will be closed. I personally prefer the even more ancient way described by Vitruvius where the shape and size of a column should be formulated on the basis of the shape of the legs of a young lady.